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WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H01M 8/00, 8/02, 8/04, 8/08, 8/10, 8/14, 8/20, 8/22

A1

(11) International Publication Number: WO 98/06145

(43) International Publication Date: 12 February 1998 (12.02.98)

(21) International Application Number: PCT/AU97/00488

(22) International Filing Date: 4 August 1997 (04.08.97)

(30) Priority Data:

PO 1486	7 August 1996 (07.08.96)	AU
PO 4376	30 December 1996 (30.12.96)	AU

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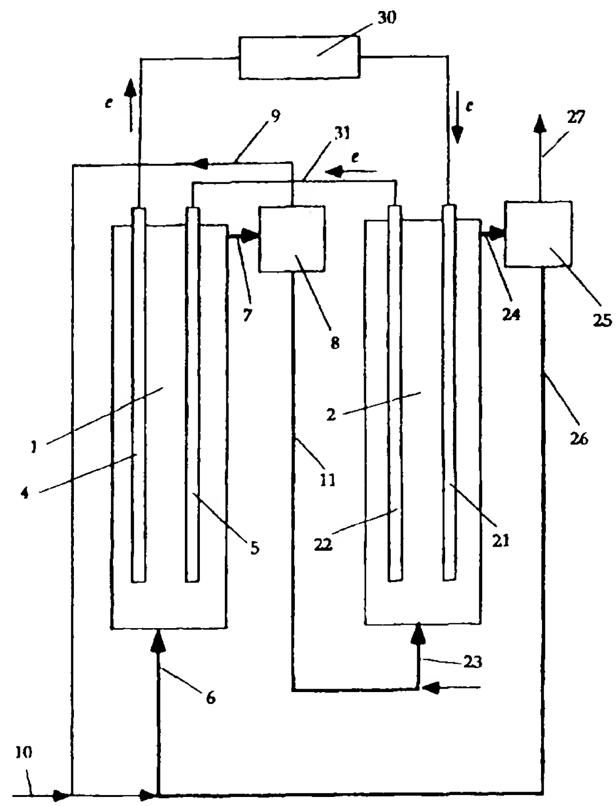
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: FUEL CELL AND A PROCESS OF USING A FUEL CELL

(57) Abstract

This process of a fuel cell system consists of a separate anode cell (1) where the fuel (6) is introduced and a separate cathode cell (2) where the oxidant (23) is introduced. The fluid electrolyte is circulated between the anode cell and the cathode cell to provide ion transport for the process while an independent set of electrodes (5, 22) immersed in the anode fluid and in the cathode fluid and joined externally by an electrical conductor (31), provide the electronic circuit. This fuel system avoids the need for diaphragms or porous electrodes between the anode and the cathode sections of fuel cells for faster reactions rates.



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FUEL CELL AND A PROCESS OF USING A FUEL CELL

FIELD OF INVENTION

This invention relates to electrical fuel cells.

BACKGROUND

US Patent 5,569,370 and Australian Patent No. 654774 concern a metal recovery process which involve a concept of connecting the solutions in an anode section and in a cathode section with a set of independent electrodes immersed in the anode and in the cathode sections and joined externally by an electrical conductor. This process avoids the use of a diaphragm between the anode and cathode sections which results in faster reaction rates favourable for commercial applications. In this electrochemical cell, a chemical reaction occurs in the solution when a potential is impressed between the anode and the cathode.

In general, a fuel cell is the opposite of an electrochemical cell; chemical reactions occur in the solution in the fuel cell and the electrons participating in the reactions are collected to form an electrical current.

PRIOR ART

One early form of the fuel cell is a diaphragm separating the anode and cathode electrodes which are immersed in the electrolyte. Fuel such as hydrogen gas is fed into the anode section where dissolved hydrogen is adsorbed on the anode electrode forming hydrogen ions and releasing electrons in acid electrolytes as follows:

(1) $$H_2 \text{ -----> } 2H^+ + 2e$$

The hydrogen ions migrate through the diaphragm into the cathode section where oxygen gas is introduced and the ions react as follows:

(2) $$2H^+ + {}^1/_2O_2 + 2e \text{ ------> } H_2O$$

There are other concepts of the reactions (1) and (2) where the OH radical is involved as described in US patent 3,615,862 (H. A. Roth et al, Oct. 26, 1971) when using an alkaline electrolyte. The electrons travel through the electrodes, the external circuit and through the electrolyte and the diaphragm. The slow reaction rates of these type of fuel cells appear to be due to the hindrance in the paths of the electrons and the ions through the diaphragm.

Another common construction of the fuel cell consists of a porous anode and a porous cathode with the electrolyte sandwiched in between as described in US Patent No. 3,510,356 (P. D. Richman, May 5, 1970). The hydrogen fuel gas is contacted outside the anode and the oxygen contacted at the outside of the cathode. Reaction (1) occurs at the anode and the hydrogen ion travels to the cathode where reaction (2) occurs. The electrons go from the anode to the external circuit to the cathode and through the electrolyte.

A more recent development is substituting a semi-conducting polymer membrane between the anode and cathode of the cell above. An example is described in International Application No. WO95/15019 (International Fuel Corporation, 1 June, 1995). At the present, this proton exchange membrane type cell appears to be limited to hydrogen fuel, and for motor vehicle application.

The Molten Carbonate Fuel Cell (MCFC) uses an electrolyte of molten lithium/potassium carbonate (reference- A.J. Appleby, J. of Power Sources, 49 (1994) 15-34.) with a ratio of 68/32 and operating at about 600 C. The molten carbonate is held in a matrix of $LiAlO_2$ powder. Air with carbon dioxide is contacted with the cathode according to the following:

(3) $$O_2 + 2CO_2 + 4e \dashrightarrow 2CO_3^{(2-)}$$

The current carrying ion is $CO_3^{(2-)}$ and reacts at the anode:

(4) $$2H_2 + 2CO_3^{(2-)} \dashrightarrow 2H_2O + 2CO_2 + 4e$$

MCFC fuel cells have the capability to accept carbon fuels but polarisation and corrosion of the nickel electrodes is a problem.

The latest in fuel cell development is the Solid Oxide Fuel Cell or SOFC

(reference: S. Baldwal and K. Folger, Ceramic International, 22, (1996) 257-265). The cell operates at about 1000 C and features a Y_2O_3 doped ZrO_3 solid electrolyte which is an oxygen ion conductor located between the lanthanum-manganite cathode and Ni/ZrO_2-cermet anode. In operation, the oxygen molecule is adsorbed at the cathode and reduced to oxygen ion and the requirement for four electrons. The oxygen ion migrates through the electrolyte to the anode where it reacts with the fuel forming water and carbon dioxide and producing electrons. SOFC can handle hydrocarbon fuels but the high temperature required creates problems of stability of the materials used.

US Patent No. 4,136,232 (Durand, Jan. 23, 1979) reported an auxiliary cathode in an electrochemical generator. In this prior art line (14) connects the anode (101) of cell (C1) to the auxiliary cathode of the next cell (C25). The intent of this prior art is to connect the two cells in series to boost power output.

It is the object or one of the objects of this invention to provide an improved fuel cell.

DESCRIPTION OF THE INVENTION

In one form therefore the invention is said to reside in a fuel cell comprising a separate anode cell and a separate cathode cell, the separate anode cell including an anode tank for containing an electrolyte and having an anode electrode immersed therein, means to supply electrolyte to the anode tank and means to supply fuel to the anode tank, the separate cathode cell including a cathode tank for containing the electrolyte and having a cathode electrode immersed therein, means to supply electrolyte to the cathode tank and means to supply an oxidant to the cathode tank, means to withdraw reacted electrolyte from the anode tank and to supply it to the cathode tank, means to withdraw reacted electrolyte from the cathode tank and to supply it to the anode tank, a first electrode immersed in the electrolyte in the anode tank adjacent but not in contact with the anode electrode, a second electrode immersed in the cathode electrolyte adjacent to but not in contact with the cathode electrode, and an external electrical connection between the first electrode and the second electrode, means to connect the anode electrode and the cathode electrode to an electrical load of the cell, wherein the electrical connection between the first electrode and the second electrode is part of the complete electrical circuit of the fuel cell including the anode

electrode, the cathode electrode, and the electrolyte between the anode and the first electrode and the cathode electrode and the second electrode.

In a preferred embodiment the means to supply electrolyte to the anode tank comprises the means to withdraw electrolyte from the cathode tank and the means to supply electrolyte to the cathode tank comprises the means to withdraw electrolyte from the anode tank.

In a preferred embodiment there may be further included a reaction vessel and wherein the respective means to supply electrolyte to the anode tank and to the anode tank comprises means to supply electrolyte from the reaction vessel and the respective means to withdraw reacted electrolyte from the anode tank and from the cathode tank transfers reacted electrolyte to the reaction tank

The fuel may be selected from the group comprising hydrogen, natural and refined hydrocarbons such as methanol, ethanol and other alcohols and natural and manufactured carbohydrates.

The oxidant may be selected from the group comprising air, oxygen, oxygen-nitrogen mixtures, oxygen-carbon dioxide mixtures and hydrogen peroxide.

There may be means for recovering excess fuel from the reacted electrolyte discharged from the anode tank and means of removing reaction products from the anode tank, the cathode tank, or the reactor vessel.

In one embodiment of the invention the first electrode and the second electrode together may form a common conductive wall between the anode tank and the cathode tank which completes the electrical circuit.

Alternatively the first electrode and the second electrode together may be a diaphragm or membrane which forms a common conductive wall between the anode tank and the cathode tank which completes the electrical circuit.

The anode electrode, the cathode electrode, and the first and the second electrodes may be made from a material selected from the group solid, porous, fibre, gauze, or woven cloth of metal, carbon, conducting plastics material, or a slurry comprising catalyst or fine particles coated with catalyst

fluidised in the respective tanks.

The anode electrode and the cathode electrode may be electroplated or coated with catalyst selected from platinum, nickel, cobalt, lithium, lanthanum, strontium, palladium, yttrium, or any mixture of these.

There may be further included a means of cracking hydrocarbon fuels or means of forming hydrogen from hydrocarbon fuels before introducing these fuels to the anode cell.

There may be further included means to heat the anode or cathode tanks to the required temperature.

There may be further included means to raise the pressure in the anode tank and in the cathode tank.

The electrolyte may be selected from the group acidic electrolytes including sulphuric acid, phosphoric acid, methane sulphonic acid, other organic and inorganic acids, alkaline electrolytes including sodium hydroxide and potassium hydroxide, molten electrolytes including lithium-potassium carbonate and dispersions of fine solids in a liquid, the fine solids or a coating on the fine solids being a catalyst for the anode reaction or the cathode reaction.

In an alternative embodiment the invention may be said to reside in a fuel cell consisting of a separate anode cell and a separate cathode cell and a reaction vessel, wherein: the anode cell comprises an anode tank, the cathode cell comprises a cathode tank, the anode tank has an anode electrode immersed therein, means to supply electrolyte to the anode tank from the cathode tank or from the reaction vessel, means to supply fuel in the form of gas, or liquid, or solid, mixed with the electrolyte, the cathode tank has a cathode electrode immersed therein, means to supply electrolyte to the cathode tank from the anode tank or from the reaction vessel, means to supply air, oxygen-nitrogen mixtures or other oxidant to the cathode tank mixed with the electrolyte, means to withdraw reacted electrolyte from the anode tank to the cathode tank or to the reaction vessel, and means to withdraw reacted electrolyte from the cathode tank to the anode tank or to the reaction vessel, a first electrode immersed in the electrolyte in the anode tank adjacent but not in contact with

the anode electrode, a second electrode immersed in the electrolyte in the cathode tank adjacent to but not in contact with the cathode electrode, and an external electrical connection between the first electrode and the second electrode, means to connect the anode electrode and the cathode electrode to an electrical load of the cell, wherein the electrical connection between the first electrode and the second electrode is part of the complete electrical circuit of the fuel cell including the anode electrode the cathode electrode, and the electrolyte between the anode electrode and the first electrode and the cathode electrode and the second electrode.

The invention may also comprise a battery of fuel cells comprising a plurality of fuel cells as described above wherein the anode electrodes and cathode electrodes are electrically connected in series or in parallel.

In an alternative form the invention is said to reside in a continuous process for producing electric power and heat in a fuel cell from reacting a fuel in a anode tank and an oxidant in a cathode tank, the fuel cell having a first electrode immersed in an electrolyte in the anode tank adjacent but not in contact with an anode, a second electrode immersed in the electrolyte in the cathode tank adjacent to but not in contact with the cathode, and an external electrical connection between the first electrode and the second electrode, the process comprising the steps of; introducing the fuel with the electrolyte in the anode tank wherein a catalyst on the anode in the anode tank causes a chemical reaction or ionises the fuel which produces electrons, transferring the electrons through an external electrical circuit through an electrical load and to the cathode in the cathode tank, introducing the oxidant with the electrolyte into the cathode tank wherein a catalyst on the cathode causes a chemical reaction or ionises the oxidant with the electrons from the anode, completing the electronic circuit through the electrolyte between the cathode and the second electrode, then through the external connection between the first and second electrode, and then through the electrolyte between the first electrode and the anode.

The ions produced at the anode required for the reaction at the cathode may be delivered continuously through the electrolyte and the ions produced at the cathode required for the reaction at the anode may be delivered continuously through the electrolyte.

There may be further included the step of recycling excess fuel exiting the anode tank to a feed of the anode tank.

There may be further included the step of removing the reaction products such as water or carbon dioxide from the electrolyte in a vacuum vessel or an absorption vessel.

The anode tank and cathode tank may be heated and pressurised.

The process may be carried out in pressures from sub-atmospheric to 5,000 pounds per square inch and at temperatures from sub-zero temperatures to 1200 degrees Celsius.

The oxidant may be selected from the group comprising air, oxygen, oxygen-nitrogen mixtures, oxygen-carbon dioxide mixtures and hydrogen peroxide and the fuel may be selected from the group comprising hydrogen, natural and refined hydrocarbons such as methanol, ethanol and other alcohols and natural and manufactured carbohydrates. A hydrocarbon fuel may be subjected to cracking, or gasification, or water-gas process to produce hydrocarbon gases or hydrogen gas which is fed as fuel to the fuel cell.

There may be further included a step of transferring the electrolyte from the anode tank and the cathode tank to a reaction vessel and transferring the electrolyte from the reaction vessel to the anode tank and the cathode tank.

Heat produced from the reaction may be recovered for co-generation, industrial heating and domestic heating.

The fuel may travel co-current or counter-current to the electrolyte in the anode tank and the oxidant may travel co-current or counter-current to the electrolyte in the cathode tank.

The first electrode and the second electrode together may form a common electrically conductive wall between the anode tank and the cathode tank and the step of completing the electronic circuit may include the step of completing the electronic circuit through the common conductive wall.

Alternatively the first electrode and the second electrode together may be a

diaphragm which forms a common electrically conductive wall between the anode tank and the cathode tank and the step of completing the electronic circuit may include the step of completing the electronic circuit through the diaphragm.

Hence it will be seen that this invention is a chemico-electrical process to collect the electrical power and heat from the reaction of fuel and an oxidant. The process is carried out in a separate anode cell where fuel and electrolyte are introduced and a separate cathode cell where the oxidant and electrolyte is introduced. A complete electrical circuit is established between the anode and the cathode cells by an independent set of electrodes immersed in the anode electrolyte and in the cathode electrolyte and these independent set of electrodes are connected externally by an electrical conductor. Ion transport within the fuel cell is accomplished by circulating the fluid electrolyte containing the ions between the anode and cathode.

BRIEF DESCRIPTION OF THE DRAWINGS

This generally describes the invention but to assist with understanding of the invention reference will now be made to the following drawings and experimental work carried out with experimental fuel cells according to the invention and the prior art.

In the drawings:

FIG 1 shows a voltage time curve for a conventional prior art fuel cell,

FIG 2 shows a voltage time curve for a fuel cell according to one embodiment of the present invention,

FIG 3 shows a voltage time curve for a fuel cell according to the embodiment of FIG 2 with a load connected,

FIG 4 shows a schematic block diagram of a fuel cell according to one embodiment of the present invention,

FIG 5 shows a schematic block diagram of a fuel cell according to an alternative embodiment of the present invention,

FIG 6 shows a schematic block diagram of a fuel cell according to a further embodiment of the present invention,

FIG 7 shows a schematic block diagram of a fuel cell according to a further embodiment of the present invention,

FIG 8 shows a schematic block diagram of a fuel cell according to a further embodiment of the present invention, and

FIG 9 shows a schematic block diagram of a fuel cell according to a further embodiment of the present invention.

EXPERIMENTAL DATA

Two laboratory size fuel cells were built to examine the process proposed in this invention. A diaphragm type cell was built as a basis of comparison for the fuel cell according to the present invention.

The diaphragm type cell measured about 240 mm x 60 mm x 25 mm (inside dimensions) with a polypropylene cloth diaphragm between the anode and cathode section. The electrodes were made of Hastelloy-C and measured 40 mm x 160 mm with 140 mm, painted with platinum black held with an organic/PTFE binder. The binder of the commercially purchased electrodes appear to be insufficiently cured and this may be the reason for the lower voltage attained in these experiments than might be expected for a fuel cell.

Using a 35 % potassium hydroxide (KOH) solution, the voltage generated as measured by a Metex Model M-3850D voltmeter when hydrogen and oxygen were passed through the anode and cathode respectively at 14 degrees Celsius is shown on FIG 1. The voltage generated by the diaphragm cell reached 313 millivolts after 31 minutes. The load following characteristics of the diaphragm cell was very poor; when the Metex ammeter with 100 ohm resistance was connected at the terminals, the voltage dropped to 1.6 mV and the current to 1.8 mA in 2.0 minutes. This provides a measure of the capability of the electrodes.

The fuel cell according to the present invention consisted of an anode cell and a cathode cell each measuring about 50 mm wide x 30 mm thick x 240 mm

high, arranged with the anode cell discharging into the cathode cell which in turn discharged into a pump box. This is similar to the arrangement as shown in FIG 5 but without means to remove reaction products. A 12-volt diaphragm type pump with a variable DC supply circulated the electrolyte from the pump box to the anode cell at about 855 millilitres per minute. Similar anode and cathode electrodes were used as in the diaphragm cell above. Solution electrodes for each cell consisted of nine (9) 3.97 mm diameter carbon rods located about 3 mm from the anode and cathode electrodes respectively. The solution electrodes were externally connected by a 1.0 mm copper wire. Temperature of the 35 % KOH electrolyte was 14 degrees Celsius.

The voltage generated by the single power cell is shown on FIG 2 where 715 millivolts was attained in 33 minutes when hydrogen was bubbled through the anode cell and oxygen through the cathode cell. This is considered a successful demonstration of the fuel cell concept without the use of a diaphragm. Slowing down the pump flow rate from 855 mls. per minute to about 512 mls. per minutes reduced significantly the rate at which the voltage of the power cell was generated. This is consistent with the concept of the fuel cell of the present invention where the electrolyte is used to carry the ions from one cell to the other.

To examine the load following characteristics of the power cell and the effect of the solution electrodes a Metex ammeter which has an estimated 100 ohm resistance was connected between the fuel cell anode and cathode. The resulting voltage curve is shown on FIG 3 with the temperature at 16 degrees Celsius. The voltage increased to about 82 millivolts after about 17 minutes; then the solution electrodes were disconnected while hydrogen and oxygen continued to be fed to the cells. The voltage generated immediately went on a downward trend reaching 47.4 millivolts at 56 minutes.

FIGS 4, 5, 6, and 7 show some examples of the application of this invention.

FIG 4 is typical of a fuel cell using an acid electrolyte such as phosphoric acid.

The fuel cell comprises an anode tank 1 and a cathode tank 2.

In the anode tank 1 there is an anode 4 and a solution electrode 5. The anode tank has an electrolyte and fuel gas inlet 6 and a reacted electrolyte and

excess fuel outlet 7. The excess fuel is extracted from the reacted electrolyte in the vacuum vessel 8 with the excess fuel being returned in line 9 to the inlet 6. Some new fuel is admitted in line 10. Hydrogen rich electrolyte is transported in line 11 to the inlet 23 to the cathode tank 2.

In the cathode tank 2 there is a cathode 21 and a solution electrode 22. The cathode tank has an electrolyte and oxidising gas inlet 23 and a reacted electrolyte, reaction product and excess oxidising gas outlet 24. The reaction product and excess oxidising gas is extracted from the reacted electrolyte in the vacuum vessel 25 with reaction product and excess oxidising gas being discarded through line 27 and the electrolyte being returned in line 26 to the to the inlet 6 of the anode tank.

The electronic circuit passes through the anode 4, to the electrical load 30, to the cathode 21, across the cathode electrolyte to the solution electrode 22, through the external conductor 31, to the solution electrode 5, across the anode electrolyte, and to the anode 4. The hydrogen ions produced by the catalyst action of platinum in the anode 4 on hydrogen, are transported to the cathode tank 2 where water is produced in a reaction with oxygen and the electrons from the anode tank 2.

The electrochemical reaction in the anode tank is;

$$H_2 \text{ -----> } 2H^+ + 2e$$

and the electrochemical reaction in the cathode tank is;

$$2H^+ + {}^1/_2O_2 + 2e \text{ ------> } H_2O$$

FIG 5 shows the process where an alkaline electrolyte is used such as potassium hydroxide.

In FIG 5 items with the same function as in FIG 4 have the same reference numbers.

Catalyst such as nickel may be used to provide in the cathode tank 2 the cathode reaction of oxygen, water, and the electrons from the anode 4, to produce the $OH^{(-)}$ ion. This is transported to the anode tank 1 where it reacts

with the hydrogen to produce water and electrons.

The fuel cell utilising an alkaline electrolyte has a condenser 13 in the excess fuel return line 9 to remove water produced in the anode cell reaction. Water is discarded through line 14

The electrochemical reaction in the anode tank is;

$$H_2 + 2OH^{(-)} \text{----->} 2H_2O + 2e$$

and the electrochemical reaction in the cathode tank is;

$$H_2O + {}^1/_2O_2 + 2e \text{------>} 2OH^{(-)}$$

Figure 6 is an example of this process used in a power cell using a molten carbonate electrolyte.

In the anode tank 40 there is an anode 41 and a solution electrode 42. The anode tank 40 has a molten electrolyte inlet 43 and fuel gas inlet 44 and a reacted electrolyte outlet 45 and excess fuel 7. The carbon dioxide produced in the anode reaction is transferred in line 47 to the oxidant inlet 48 to the cathode cell 50.

In the cathode tank 50 there is a cathode 51 and a solution electrode 52. The cathode tank 50 has a molten electrolyte inlet 53 and oxidising gas inlet 48 and a regenerated electrolyte outlet 55. Additional or make up oxidant such as oxygen or air is also added through oxidant inlet 48.

The electronic circuit passes through the anode 41, to the electrical load 56, to the cathode 51, across the cathode electrolyte to the solution electrode 52, through the external conductor 57, to the solution electrode 42, across the anode electrolyte, and to the anode 41.

The $CO_3^{(2-)}$ ion is produced at the cathode 51 using oxygen, carbon dioxide which is re-cycled from the anode cell 40, and electrons from the anode 41. The $CO_3^{(2-)}$ ions are transported to the anode cell 40 by the molten electrolyte where it reacts with the fuel to form water, carbon dioxide, and electrons. The molten electrolyte may be circulated by mechanical means or

using pressure differential between the anode cell and the cathode cell.

The electrochemical reaction in the anode tank is;

$$2H_2 + 2CO_3^{(2-)} \longrightarrow 2H_2O + 2CO_2 + 4e$$

and the electrochemical reaction in the cathode tank is;

$$O_2 + 2CO_2 + 4e \longrightarrow 2CO_3^{(2-)}$$

Figure 7 shows the application of this process where the fuel and oxidant are catalysed independently and the ions produced are reacted in a reaction vessel. This configuration may avoid the poisoning of the catalyst in either the anode or cathode. It may also segregate the heat produced from the process to provide convenient co-generation applications.

In FIG 7 items with the same function as in FIG 4 have the same reference numbers.

The reacted electrolyte outlet 7 from the anode tank 1 is first separated from excess fuel in vacuum separator 8 and is then passed to reaction vessel 15. The reacted electrolyte outlet 16 from the cathode tank 1 is passed to reaction vessel 15. In the reaction vessel 15 the hydrogen ions from the anode tank and the oxygen ions from the cathode tank are reacted to produce water. The water is removed and discarded through line 17. The purified electrolyte is then returned to both the anode tank through inlet 6 and the cathode tank 2 through inlet 23.

The reactions that occur are as follows.

The electrochemical reaction in the anode tank is;

$$H_2 \longrightarrow 2H^+ + 2e$$

the electrochemical reaction in the cathode tank is;

$${}^1/{}_2O_2 + 2e \longrightarrow O^{(2-)}$$

and the reaction in the reaction vessel is;

$$2H^+ + O^{(2-)} \text{------>} H_2O$$

FIG 8 shows an alternative embodiment of a fuel cell .

The fuel cell comprises an anode tank 60 and a cathode tank 61 which are joined by a common wall 62 which is a porous diaphragm or a solid conducting diaphragm.

In the anode tank 60 there is an anode 65 and the solution electrode is the diaphragm 62. The anode tank has an electrolyte and fuel gas inlet 66 and a reacted electrolyte and excess fuel outlet 67. The excess fuel is extracted from the reacted electrolyte in the vacuum vessel 68 with the excess fuel being returned in line 69 to the inlet 66. Some new fuel is admitted in line 70. Reacted electrolyte is transported in line 71 to the inlet 73 to the cathode tank 61.

In the cathode tank 61 there is a cathode 75 and the solution electrode is the diaphragm 62. The cathode tank has an electrolyte inlet 73 and oxidising gas inlet 74 and a reacted electrolyte, reaction product and excess oxidising gas outlet 76. The reaction product and excess oxidising gas is extracted from the reacted electrolyte in the vacuum vessel 77 with reaction product and excess oxidising gas being discarded through line 78 and the electrolyte being returned in line 79 to the to the inlet 66 of the anode tank.

The electronic circuit passes through the anode 65, to the electrical load 79, to the cathode 75, across the cathode electrolyte to the diaphragm 62, through the external conductor connection which is in effect the thickness of the diaphragm 62 across the anode electrolyte, and to the anode 65.

The fuel cell of this embodiment may be an acid or alkali type electrolyte cell.

FIG 9 shows an alternative embodiment of a fuel cell .

The fuel cell comprises an anode tank 60 and a cathode tank 61 which are joined by a common wall 62 which is a porous diaphragm or a solid conducting diaphragm.

In the anode tank 60 there is an anode 65 and the solution electrode is the diaphragm 62. The anode tank has an electrolyte and fuel gas inlet 66 and a reacted electrolyte and excess fuel outlet 67. The excess fuel is extracted from the reacted electrolyte in the vacuum vessel 68 with the excess fuel being returned in line 69 to the inlet 66. Some new fuel is admitted in line 70. Reacted electrolyte is transported in line 71 to a reaction vessel 80.

In the cathode tank 61 there is a cathode 75 and the solution electrode is the diaphragm 62. The cathode tank has an electrolyte inlet 73 and oxidising gas inlet 74 and a reacted electrolyte, reaction product and excess oxidising gas outlet 76. The reacted electrolyte, reaction product and excess oxidising gas is transported in line 82 to reaction vessel 80 with reaction product and excess oxidising gas being discarded through line 81. The reacted electrolyte from both the cathode tank 60 and the cathode tank 61 are reacted in the reaction vessel 80 and then the purified electrolyte is transferred through lines 66 and 73 to the respective tanks.

The electronic circuit passes through the anode 65, to the electrical load 79, to the cathode 75, across the cathode electrolyte to the diaphragm 62, through the external conductor connection which is in effect the thickness of the diaphragm 62 across the anode electrolyte, and to the anode 65.

The fuel cell of this embodiment may be an acid or alkali type electrolyte cell.

Throughout this specification and the claims that follow unless the context requires otherwise the terms 'comprise' and 'include' and variations such as 'comprising' and 'including' will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

CLAIMS

1. A fuel cell comprising a separate anode cell and a separate cathode cell,

the separate anode cell including an anode tank for containing an electrolyte and having an anode electrode immersed therein, means to supply electrolyte to the anode tank and means to supply fuel to the anode tank,

the separate cathode cell including a cathode tank for containing the electrolyte and having a cathode electrode immersed therein, means to supply electrolyte to the cathode tank and means to supply an oxidant to the cathode tank,

means to withdraw reacted electrolyte from the anode tank and to supply it to the cathode tank,

means to withdraw reacted electrolyte from the cathode tank and to supply it to the anode tank,

a first electrode immersed in the electrolyte in the anode tank adjacent but not in contact with the anode electrode, a second electrode immersed in the cathode electrolyte adjacent to but not in contact with the cathode electrode, and an external electrical connection between the first electrode and the second electrode,

means to connect the anode electrode and the cathode electrode to an electrical load of the cell,

wherein the electrical connection between the first electrode and the second electrode is part of the complete electrical circuit of the fuel cell including the anode electrode, the cathode electrode, and the electrolyte between the anode and the first electrode and the cathode electrode and the second electrode.

2. A fuel cell as on Claim 1 wherein the means to supply electrolyte to the anode tank comprises the means to withdraw electrolyte from the cathode tank.

3. A fuel cell as on Claim 1 wherein the means to supply electrolyte to the cathode tank comprises the means to withdraw electrolyte from the anode tank.

4. A fuel cell as on Claim 1 further including a reaction vessel and wherein the respective means to supply electrolyte to the anode tank and to the anode tank comprises means to supply electrolyte from the reaction vessel and the respective means to withdraw reacted electrolyte from the anode tank and from the cathode tank transfers reacted electrolyte to the reaction tank

5. A fuel cell as on Claim 1 wherein the oxidant is selected from the group comprising air, oxygen, oxygen-nitrogen mixtures, oxygen-carbon dioxide mixtures and hydrogen peroxide.

6. A fuel cell as in Claim 1 further including means for recovering excess fuel from the reacted electrolyte discharged from the anode tank,

7. A fuel cell as in Claim 1 further including means of removing reaction products from the anode tank, the cathode tank, or the reactor vessel.

8. A fuel cell as in Claim 1 wherein the first electrode and the second electrode together form a common conductive wall between the anode tank and the cathode tank.

9. A fuel cell as in Claim 1 wherein the first electrode and the second electrode together are a diaphragm which forms a common conductive wall between the anode tank and the cathode tank.

10. A fuel cell as in claim 1 wherein the anode electrode, the cathode electrode, and the first and the second electrodes are made from a material selected from the group solid, porous, fibre, gauze, or woven cloth of metal, carbon, conducting plastics material or a slurry comprising fine particles comprising catalyst or coated with catalyst fluidised in the respective tanks.

11. A fuel cell as in Claim 1 wherein the anode electrode and the cathode electrode is electroplated or coated with catalyst selected from platinum, nickel, cobalt, lithium, lanthanum, strontium, palladium, yttrium, or any mixture of these.

12. A fuel cell as in Claim 1 wherein the fuel is selected from the group comprising hydrogen, natural and refined hydrocarbons such as methanol, ethanol and other alcohols and natural and manufactured carbohydrates.

13. A fuel cell as in Claim 12 further including a means of cracking hydrocarbon fuels or means of forming hydrogen from hydrocarbon fuels before introducing these fuels to the anode cell.

14. A fuel cell as in Claim 1 wherein the electrolyte is selected from the group acidic electrolytes including sulphuric acid, phosphoric acid, methane sulphonic acid, other organic and inorganic acids, alkaline electrolytes including sodium hydroxide and potassium hydroxide, molten electrolytes including lithium-potassium carbonate and dispersions of fine solids in a liquid, the fine solids or a coating on the fine solids being a catalyst for the anode reaction or the cathode reaction.

15. A fuel cell as in Claim 1 further including means to heat the anode or cathode tanks to the required temperature.

16. A fuel cell as in Claim 1 further including means to raise the pressure in the anode tank and in the cathode tank.

17. A fuel cell consisting of a separate anode cell and a separate cathode cell and a reaction vessel, wherein:

the anode cell comprises an anode tank, the cathode cell comprises a cathode tank,

the anode tank has an anode electrode immersed therein,

means to supply electrolyte to the anode tank from the cathode tank or from the reaction vessel,

means to supply fuel in the form of gas, or liquid, or solid, mixed with the electrolyte,

the cathode tank has a cathode electrode immersed therein,

means to supply electrolyte to the cathode tank from the anode tank or from the reaction vessel,

means to supply air, oxygen-nitrogen mixtures or other oxidant to the cathode tank mixed with the electrolyte,

means to withdraw reacted electrolyte from the anode tank to the cathode tank or to the reaction vessel, and

means to withdraw reacted electrolyte from the cathode tank to the anode tank or to the reaction vessel,

a first electrode immersed in the electrolyte in the anode tank adjacent but not in contact with the anode electrode, a second electrode immersed in the electrolyte in the cathode tank adjacent to but not in contact with the cathode electrode, and an external electrical connection between the first electrode and the second electrode,

means to connect the anode electrode and the cathode electrode to an electrical load of the cell,

wherein the electrical connection between the first electrode and the second electrode is part of the complete electrical circuit of the fuel cell including the anode electrode the cathode electrode, and the electrolyte between the anode electrode and the first electrode and the cathode electrode and the second electrode.

18. A battery of fuel cells comprising a plurality of fuel cells as in any one of claims 1 to 17 wherein the anode electrodes and cathode electrodes are electrically connected in series or in parallel.

19. A continuous process for producing electric power and heat in a fuel cell from reacting a fuel in a anode tank and an oxidant in a cathode tank,

the fuel cell having a first electrode immersed in an electrolyte in the anode tank adjacent but not in contact with an anode, a second electrode immersed in the electrolyte in the cathode tank adjacent to but not in contact with the cathode, and an external electrical connection between the first electrode and the second electrode,

the process comprising the steps of;

introducing the fuel with the electrolyte in the anode tank wherein a catalyst on the anode in the anode tank causes a chemical reaction or ionises the fuel which produces electrons,

transferring the electrons through an external electrical circuit through an electrical load and to the cathode in the cathode tank,

introducing the oxidant with the electrolyte into the cathode tank wherein a catalyst on the cathode causes a chemical reaction or ionises the oxidant with the electrons from the anode,

completing the electronic circuit through the electrolyte between the cathode and the second electrode, then through the external connection between the first and second electrode, and then through the electrolyte between the first electrode and the anode.

20. The process as in Claim 19 wherein the ions produced at the anode required for the reaction at the cathode are delivered continuously through the electrolyte.

21. The process as in Claim 19 wherein the ions produced at the cathode required for the reaction at the anode are delivered continuously through the electrolyte.

22. The process as in Claim 19 further including the step of recycling excess fuel exiting the anode tank to a feed of the anode tank.

23. The process as in Claim 19 further including the step of removing the reaction products such as water or carbon dioxide from the electrolyte in a vacuum vessel or an absorption vessel.

24. The process as in Claim 19 where the anode tank and cathode tank are heated.

25. The process as in Claim 19 where the anode tank and cathode tank are pressurised.

26. The process as in Claim 19 where the oxidant is selected from the group comprising air, oxygen, oxygen-nitrogen mixtures, oxygen-carbon dioxide mixtures and hydrogen peroxide.

27. The process as in Claim 19 wherein the fuel is selected from the group comprising hydrogen, natural and refined hydrocarbons such as methanol, ethanol and other alcohols and natural and manufactured carbohydrates.

28. The process as in Claim 27 wherein the hydrocarbon fuel is subjected to cracking, or gasification, or water-gas process to produce hydrocarbon gases or hydrogen gas which is fed as fuel to the fuel cell.

29. The process as in Claim 19 further including a step of transferring the electrolyte from the anode tank and the cathode tank to a reaction vessel and transferring the electrolyte from the reaction vessel to the anode tank and the cathode tank.

30. The process as in Claim 19 wherein heat produced from the reaction is recovered for co-generation, industrial heating and domestic heating.

31. The process as in Claim 19 wherein the fuel travels co-current or counter-current to the electrolyte in the anode tank and the oxidant travels co-current or counter-current to the electrolyte in the cathode tank.

32. The process as in Claim 19 wherein the electrolyte is selected from the group acidic electrolytes including sulphuric acid, phosphoric acid, methane sulphonic acid, other organic and inorganic acids, alkaline electrolytes including sodium hydroxide and potassium hydroxide, molten electrolytes including lithium-potassium carbonate and dispersions of fine solids in a liquid, the fine solids or a coating on the fine solids being a catalyst for the anode reaction or the cathode reaction.

33. A process as in claim 19 wherein the anode electrode, the cathode electrode, and the first and the second electrodes are made from a material selected from the group solid, porous, fibre, gauze, or woven cloth of metal, carbon, conducting plastics material or a slurry comprising fine particles coated with catalyst fluidised in the respective tank.

34. A process as in claim 19 wherein the first electrode and the second electrode together form a common electrically conductive wall between the anode tank and the cathode tank and the step of completing the electronic circuit includes the step of completing the electronic circuit through the common conductive wall.

35. A process as in claim 19 wherein the first electrode and the second electrode together are a diaphragm which forms a common electrically conductive wall between the anode tank and the cathode tank and the step of completing the electronic circuit includes the step of completing the electronic circuit through the diaphragm.

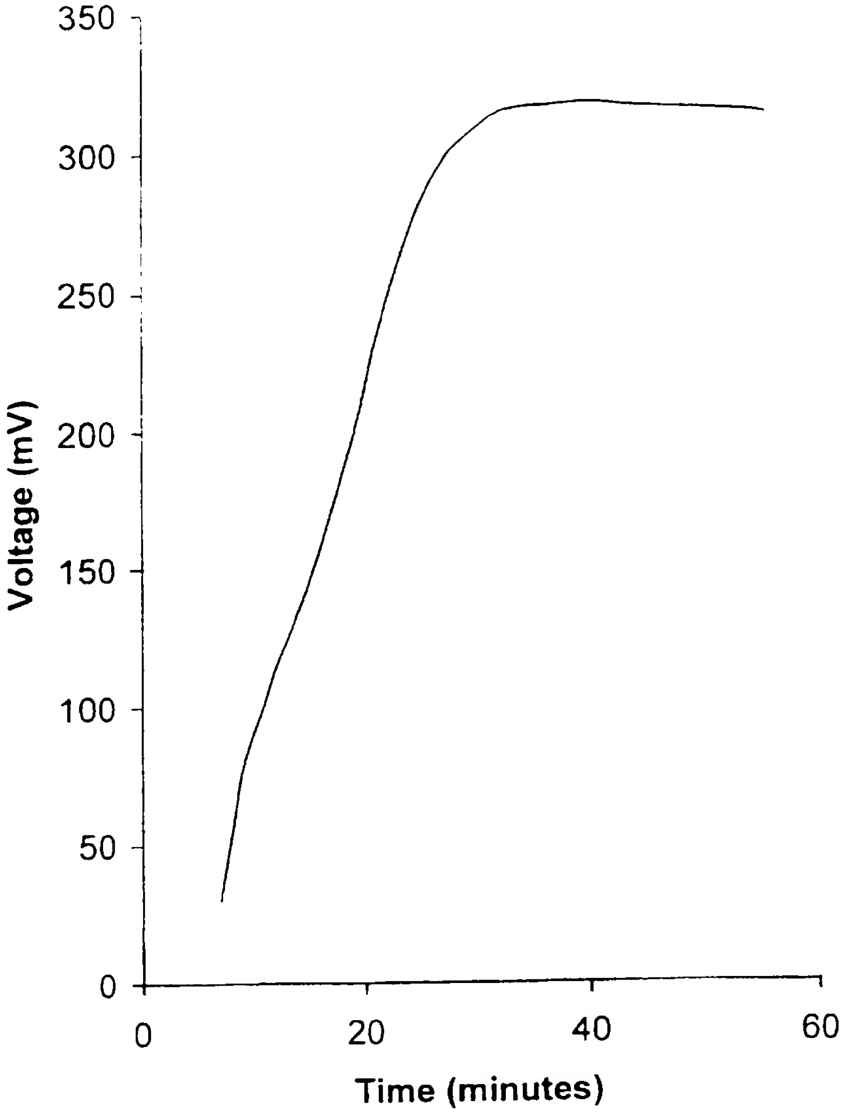


FIG 1

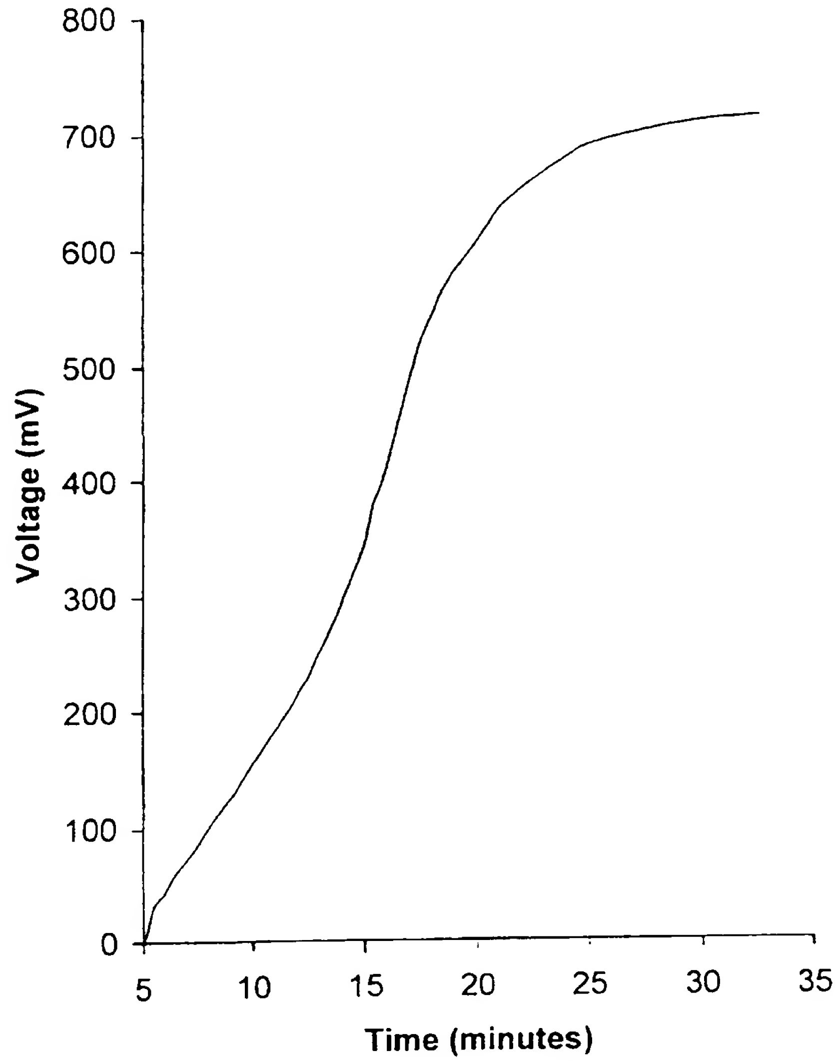
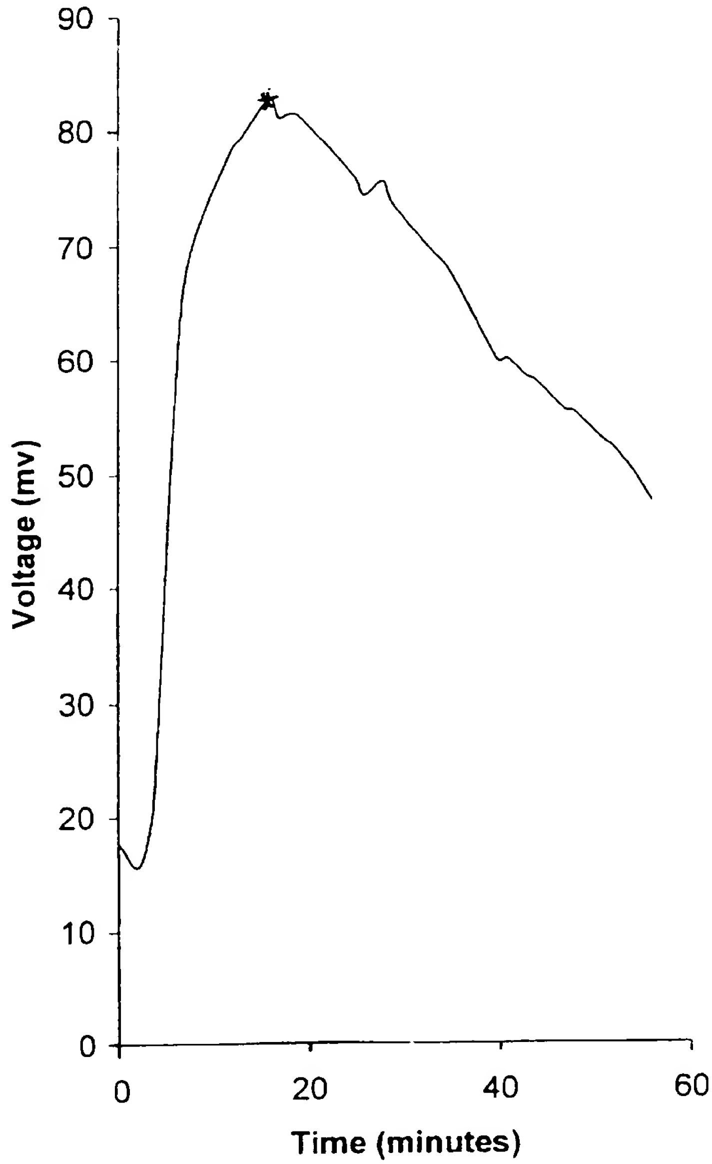

800
700
600
500
400
300
200
100
0
Voltage (mV)
5
10
15
20
25
30
35
Time (minutes)

FIG 2



* Solution electrodes disconnected

FIG 3

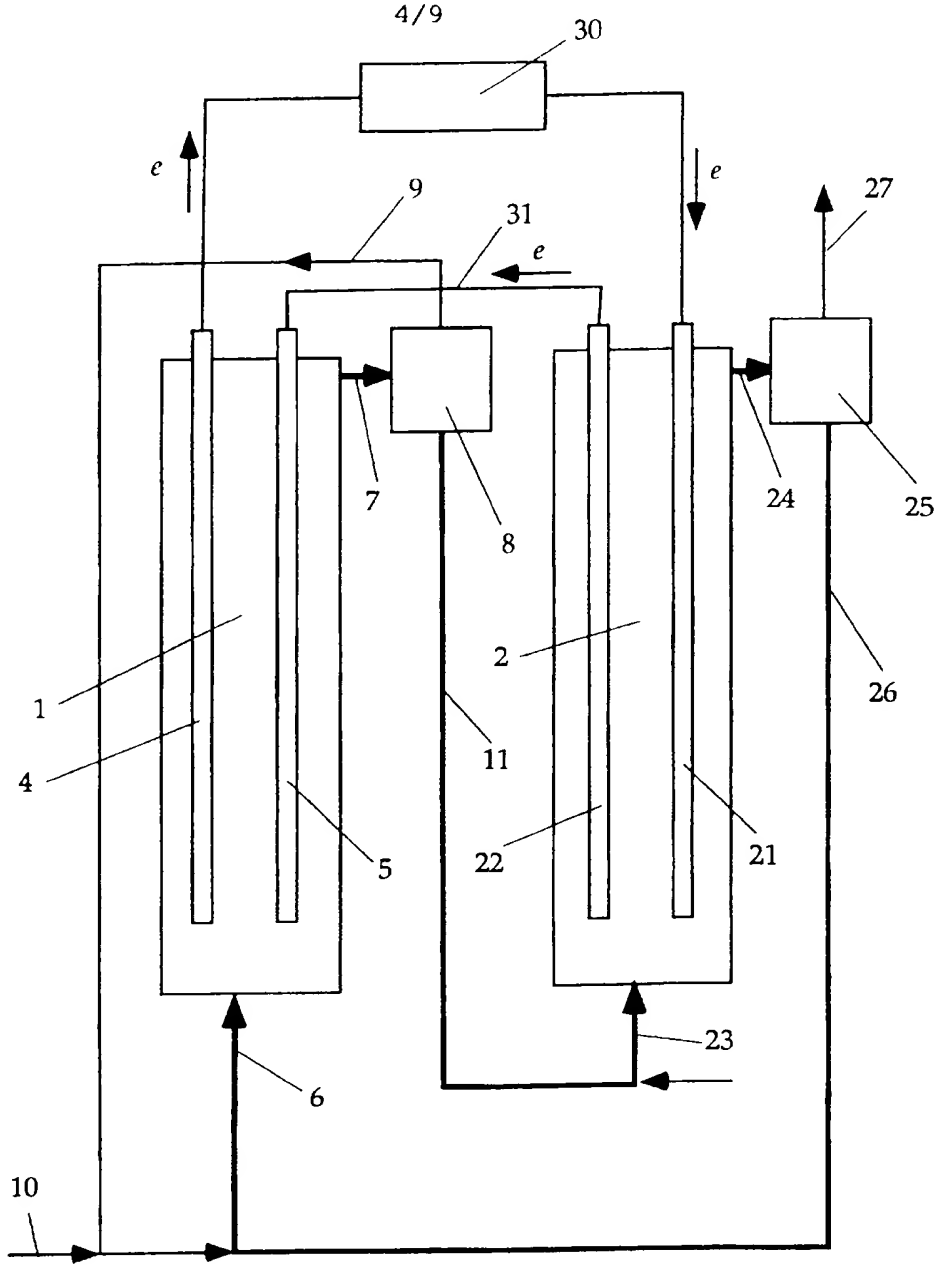


FIG 4

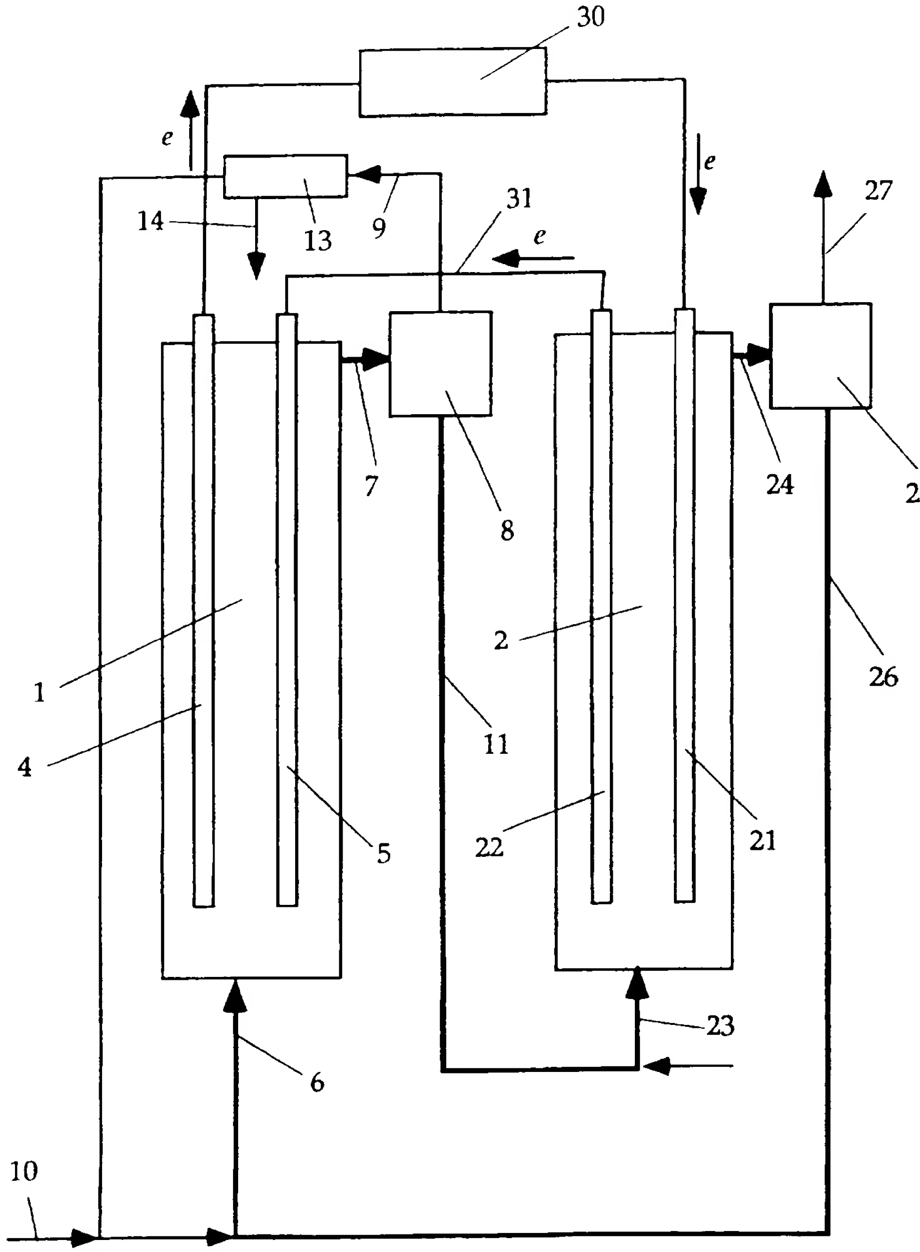


FIG 5

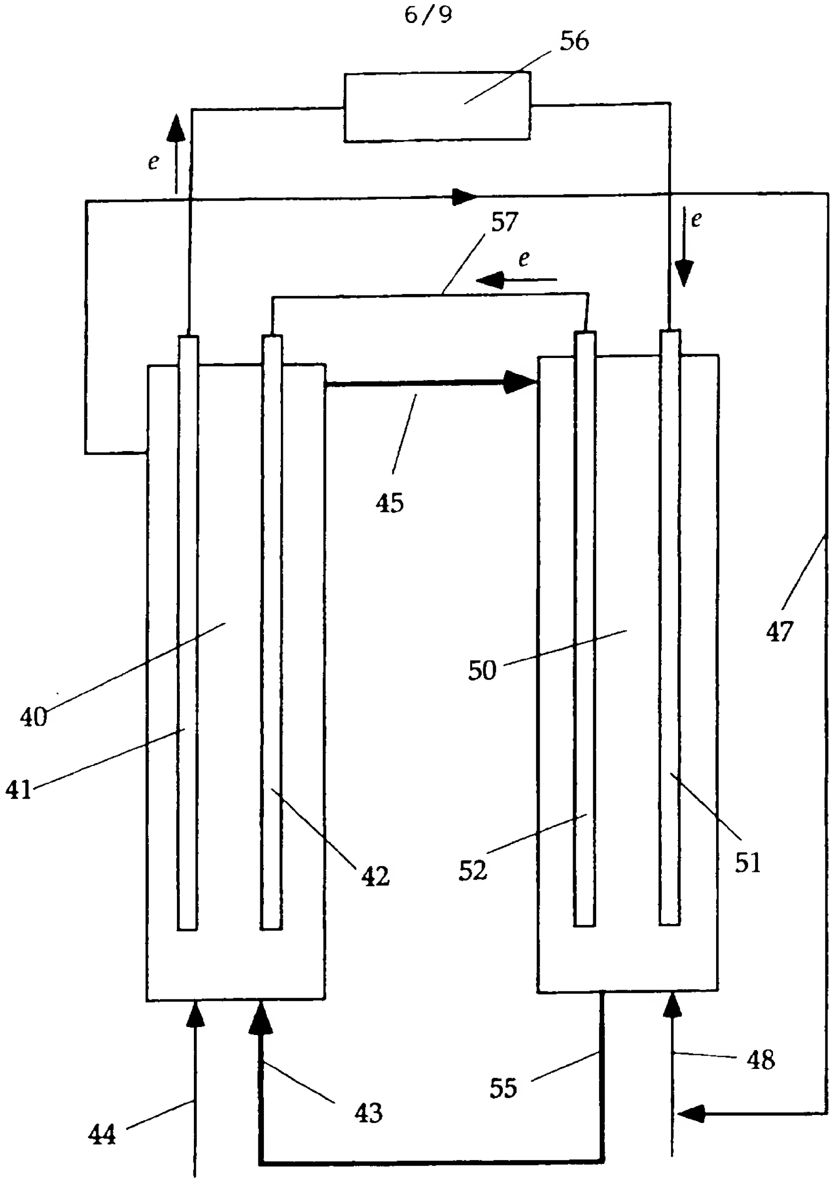


FIG 6

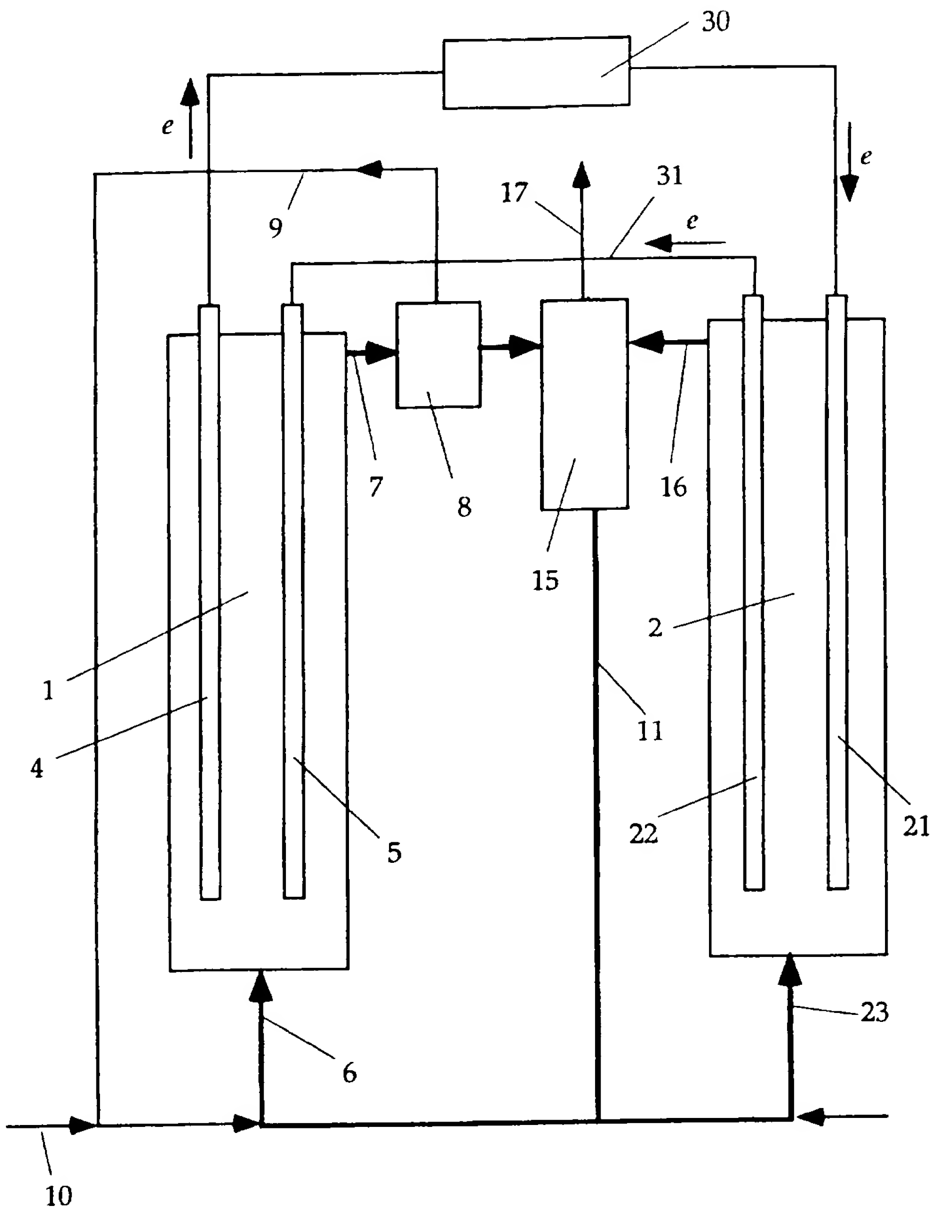


FIG 7

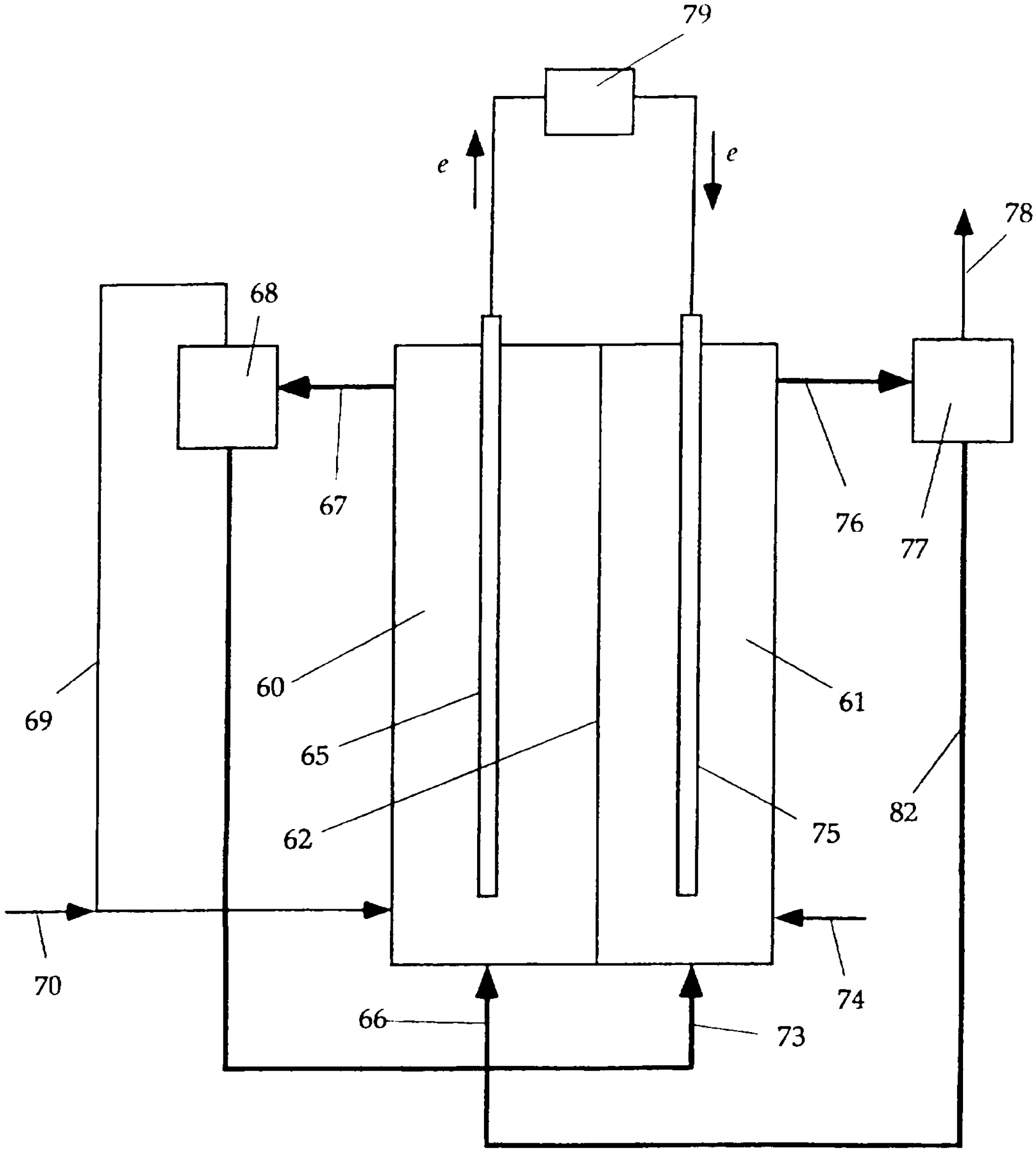


FIG 8

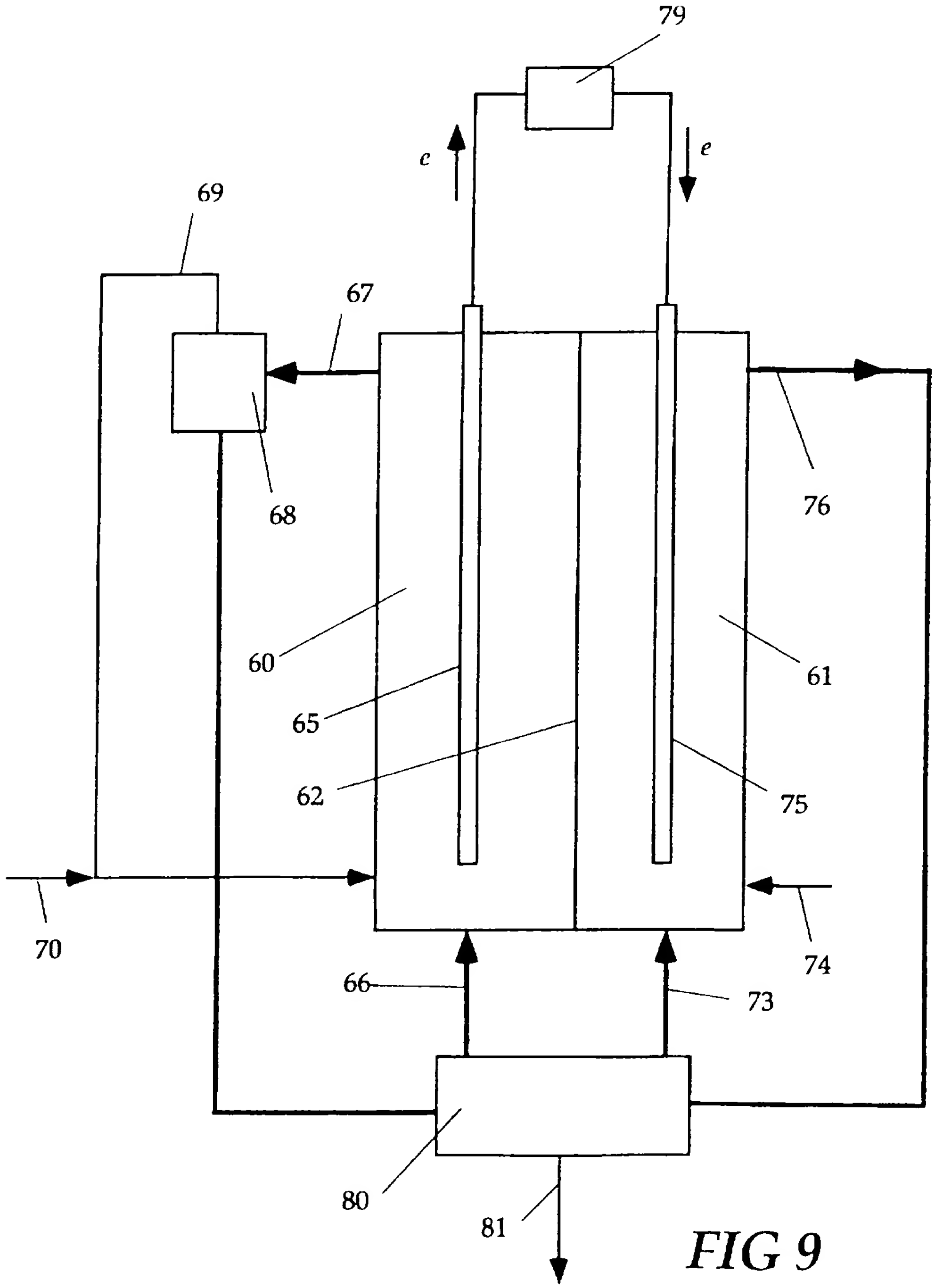


FIG 9

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00488

A.	**CLASSIFICATION OF SUBJECT MATTER**
Int Cl^{6}	H01M 8/00, 8/02, 8/04, 8/08, 8/10, 8/14, 8/20, 8/22
According to International Patent Classification (IPC) or to both national classification and IPC	
B.	**FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC : H01M 8/00, 8/02, 8/04, 8/08, 8/14, 8/20, 8/22 + KEYWORDS

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC AS ABOVE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT (as above) + AUXILLARY OR SOLUTION OR SECOND OR SEPARATE OR DUAL OR FURTHER OR EXTRA OR SUPPLEMENTARY + ELECTRODE OR ANODE OR CATHODE
JAPIO (as above) + AUXILLARY OR SOLUTION OR SECOND OR SEPARATE OR DUAL OR FURTHER OR EXTRA OR SUPPLEMENTARY + ELECTRODE OR ANODE OR CATHODE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	JP 61-22574 A (SUMITOMO DENKI KOGYO K.K.) 31 January 1986	
X	ABSTRACT	1,9
A	ABSTRACT	

[X] Further documents are listed in the continuation of Box C   [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 August 1997	26 AUG 1997
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929	Authorized officer DAVID BELL Telephone No.: (02) 6283 2309

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00488

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	JP 61-22575 A (SUMITOMO DENKI KOGYO K.K.) 31 January 1986	
X	ABSTRACT	1,9
A	ABSTRACT	
	JP 63-24565 A (TOKUYAMA SODA CO LTD) 1 February 1988	
X	ABSTRACT	1, 9
A	ABSTRACT	
	US 5366824 A (NOZAKI et al) 22 November 1994	
A	Whole document	
	WO 9011625 A (ALCAN INTERNATIONAL LTD) 4 October 1990	
A	Whole document	
	US 4529670 A (FINDL) 16 July 1985	
A	Whole document	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No.
PCT/AU 97/00488

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4529670						
WO	9011625	AU US	54170/90 5260144	CA	1315840	EP	464111
US	5366824	JP	6140062				
JP	63024565						
JP	61022574						
JP	61022575						
							END OF ANNEX